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MICROWAVE SOIL DRYING AS AN AID IN SCHEDULING IRRIGATION

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SUMMARY: Soil water content is an important aspect of computer-based irrigation scheduling programs. A study was conducted to compare a household microwave oven and a forced air drying oven as methods of determining soil water content. Gravimetric soil water determinations require a drying time of 24 hours at 105°C in a forced air drying oven. Use of a microwave oven reduced the time from 24 hrs to approximately 20 min. Comparisons of soil water contents and irrigation scheduling results from each drying method is shown. A conventional household micowave oven allows quicker updating of irrigation scheduling programs.

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INTRODUCTION

Soil water content is a critical factor required in any irrigation scheduling program. It is used to determine when and, indirectly, how much water to apply to the crop. When using a computer-based scheduling program it is useful to periodically update predicted soil water content with measured soil water contents, such as gravimetric values. Usually, in the gravimetric method, soil samples are dried in a conventional forced air oven, for at least 24 hours at 105^{o}C. However, this equipment is not normally available outside a laboratory, and the extensive time required for this method reduces its value in the timely updating of irrigation scheduling programs. A faster drying method would greatly improve the utility of this method.

Microwave drying has been studied by Miller et al. (1974) to determine moisture content of two soils of different texture and different sample size. They found that soil drying can be accomplished in approximately 20 minutes in a microwave oven and drying times varied with soil type and sample size. Routledge et al. (1976) used a microwave oven to dry soils for use in a basic soils laboratory class. In preliminary trials they found air dry sandy and clayey soil lost free moisture in twenty minutes in a microwave oven and did not lose additional moisture when transferred to a forced air oven for twenty-four hours. Results were the same for these soils at a higher moisture content near the upper limit of available water.

Others have studied the use of microwave ovens for drying materials such as alfalfa, sorghum leaves, soybeans, and several grain crops (Gorakhpurwalla et al. 1975, Verma and Noomhorm, 1983). They concluded that microwave ovens speed the drying process and provide results comparable to those obtained when samples were dried by conventional means.

In most computer-based irrigation scheduing techniques, it is recommended that the system be reinitialized periodically during the growing season by entering measured volumetric water content, by layer, for the soil profile. This procedure corrects any error that may have accumulated in the computer program since the last initialization. Measured soil water content for both initialization and periodic reinitializations is typically obtained using the gravimetric method. Often several days pass between soil sample collection and soil water content determination because of the 24-hr drying time. Unfortunately, this delay often occurs at a time in the growing season when irrigation may be critically needed. Ideally, measured soil water contents would be available the same day that samples are collected.

MATERIALS AND METHODS

Soil water contents were computed for soil samples dried in either a microwave oven or in a conventional forced air oven. Computed soil water contents were also used to update a computer-based irrigation scheduling procedure where separate computer files were maintained for each method to determine any cumulative effect of the reinitialization water contents on performance of the scheduling program.

Irrigation was scheduled for corn at two sites, one located adjacent to the Coastal Plains Soil and Water Conservation Research Center (CP) in Florence,S. C. and the other located at the Pee Dee Research and Education Center (PD) approximately sixteen (16) km away. Soil type at both sites was Norfolk loamy fine sand. At two locations in the irrigated areas, duplicate soil samples were taken. They were thoroughly mixed and divided into two subsamples, one for each drying method. Samples were taken at each of seven depths at each location in 0.15-m increments, except for the deepest increment which was 0.3 m. This resulted in 14 samples each for the microwave and forced air methods. Moisture determinations for each oven method were then averaged to give values for each depth and drying method and were used in the irrigation scheduling program. Although plant roots normally do not reach that depth, soil samples were taken to a depth of 1.2 m to completely describe the soil profile. Samples were taken four times during the growing season. Three of the four samples were collected following rainfall to evaluate profile wetting and to compare the computer projections with measured soil water storage.

The irrigation scheduling technique used in this study was a computer-based water balance (CBWB) procedure that was developed for use in a 3-year regional irrigation scheduling study for corn (Lambert, 1980). The CBWB operates on a personal computer and requires site-specific data for initialization, and both weather and crop data on a daily basis. The CBWB utilizes daily maximum and minimum temperature, solar radiation, rooting depth, rainfall, and irrigation as inputs to calculate evapotranspiration (ET) and volumetric water content of the soil profile within the crop root zone. ET was estimated using the Jensen-Haise equation (Jensen and Haise, 1963). Daily rooting depth was estimated from periodic observations of root growth and experience. The maximum rooting depth observed was about 0.7 m. The CBWB was operated twice each week in an effort to maintain soil water in the root zone between 50 and 80% of total available water. Each time the CBWB was operated, ET and soil-water content were calculated for the days since the last update using measured values and for the next five days using forecasts provided by the National Weather Service Office in Columbia, SC.

The CBWB was initialized at the beginning of the crop season by entering measured volumetric soil water content by layer for the entire soil profile and the upper and lower limits of available water for each layer. Other site-specific data such as planting and emergence dates, soil type, corn hybrid, length of growing season, and plant population were also entered at this time. Measured weather data were obtained from an automatic weather station located at the Coastal Plains Soil and Water Conservation Research Center. The CBWB was normally updated on Monday and Thursday using data and forecasts for the next five days. The CBWB update also included measured soil moisture data if any were available.

Irrigation was applied according to the conventionally-determined soil-water values but was not applied by the microwave-determined values. However, separate soil water content values were calculated for comparison of the two methods. Moisture values for each of the drying methods were then used in the CBWB. The CBWB was operated separately using soil water content values for each method using the same values for all other parameters. Separate computer files were maintained for the two methods to determine any cumulative differences for the entire growing season.

Soil samples were placed in cans with close-fitting lids immediately after collection in the field and weighed as soon as possible. Samples to be dried in the forced air oven were placed in the oven after weighing and removal of lids. Samples to be dried in the microwave oven were transferred to glass containers before they were weighed and placed in the oven. The glass containers were conventional 400-ml beakers readily available from most scientific supply companies. A soil sample approximately 100 g in size was placed in each beaker. Only 5-7 samples were dried at one time because of limited space in the microwave oven.

A beaker of water covered with a watch glass was placed in the oven to prevent damage to the magnetron as water in the soil was removed. The microwave was operated for a period of twenty (20) minutes at full power (1500 watts). The microwave oven was an Amana Radarange[1] model #RR7700.

After drying was completed, samples were weighed again. The samples dried in the microwave were then returned to the cans and placed in the forced air oven for additional drying. Samples were removed from this oven after 24 hours at 105°C and weighed again. Because the forced air oven was considered the standard, samples dried by this method were not placed in the microwave after drying.

RESULTS AND DISCUSSION

Mean water contents for soil samples dried by the forced-air-oven and microwave-oven methods for two sites are included in Table 1. At the CP site the mean soil water contents were almost equal (14.49 vs. 14.25) and the standard deviation was moderately low (3.35 and 3.28). At the PD site, only 14 samples were evaluated and there was a greater difference between the two methods (14.42 vs. 13.57) and the standard deviation was greater (5.57 and 5.30).

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[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Water contents determined by the two drying methods for soil samples at both sites, all soil depths, and all sampling dates are plotted in Figure 1. Regression analysis of these data resulted in an R^2 value of 0.92 and a best-fit linear relationship between microwave values (MW) and forced-air values (OV) of

MW = 0.747 + 0.936 OV

Although the slope of 0.936 is slightly different from 1.000 and the intercept does not pass through zero, the relationship is acceptable when one considers the possible error in determination of these values.

In an attempt to isolate differences between the two drying methods and to isolate error sources, soil water contents for all depths were plotted separately for the two sampling sites (Figure 2). This resulted in slightly different values for R^2 (0.90 and 0.98), for the slope of the linear relationship (0.932 and 0.943), and for the intercept of the linear relationship (0.946 and -0.033) for the CP and PD sites, respectively. Generally, these differences are small and partly reflect the effect of texture on soil water content and slight differences in soil horizon depth between sites. To further explore these effects, soil water content determined by the two methods were plotted as a function of sampling date separately for two soil-depth ranges (Figure 3). Again, the two drying methods provided similar results, although there was some crossing with time for the two drying methods, indicating that neither method was consisently higher or lower than the other method. We concluded that the slight differences observed between the two drying methods for individual samples could not be definitely attributed to soil texture, sampling site, or soil layer. Consequently, these differences were probably caused by normal error in determing values by each method.

Throughout the season, the irrigation scheduling program (CBWB) indicated similar soil water content profiles and irrigation schedules for the two soil-moisture determination methods. Irrigation was indicated for the same days for both soil drying methods with two exceptions, each reflecting a difference of one day. In the first case, early in the season, the microwave method indicated the need for irrigation one day before the conventional method indicated it. The second exception occurred later in the season when the conventional method indicated the need for irrigation one day before the microwave method indicated it. Any difference in soil water content used to initialize the CBWB would be reflected in the water content predicted by the model until the next initialization, and possibly until the end of the season. If the magnitude of the preicted water content becomes great enough, the CBWB would indicate the need for irrigation a day or more before or after the conventional drying method. If this occurred consistently through the season when multiple reinitializations were implemented, it would indicate that the microwave drying method produced different results. This did not occur in this study as the two exceptions indicated the microwave values were high one time and low the other time. Consequently, we concluded that the microwave method provided resasonable soil water content values. Any differences observed disappeared after the next measured soil water content values were entered into the computer program.

SUMMARY AND CONCLUSIONS

A soil-drying method utilizing a household microwave oven was compared with the conventional soil-drying method using a forced-air oven for determining soil water content gravimetrically. The soil water contents determined by the two drying methods were used to initialize and reinitialize a computer-based water balance for scheduling irrigation. Separate computer files were maintained for each drying methods for the entire growing season to determine any differences in predicted irrigation dates for the two methods. Soil water contents determined by the two drying methods were not different for the two sites, multiple sampling depths, and multiple sampling dates in this study. Also, there were no consistent differences in predicted irrigatiion dates by the CBWB when soil-water contents determined by the two drying methods were compared.

The 24-hour drying time in a forced-air drying oven is generally not feasible for a farmer or irrigation manager when attempting to initialize or reinitialize computer-based irrigation scheduling programs. A drying time of 20 minutes in a microwave oven offers a more feasible situation for the irrigation manager and a more timely update of the irrigation scheduling procedure.

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Table 1. Water contents for the oven dried and microwave dried soil samples for the two sites.

Location*	No. of Samples	Drying Method	Water Content (kg/kg)	
			Mean	Standard Deviation
CP	70	OD	14.49	3.35
		MW	14.45	3.28
PD	14	OD	14.42	5.57
		MW	13.57	5.30

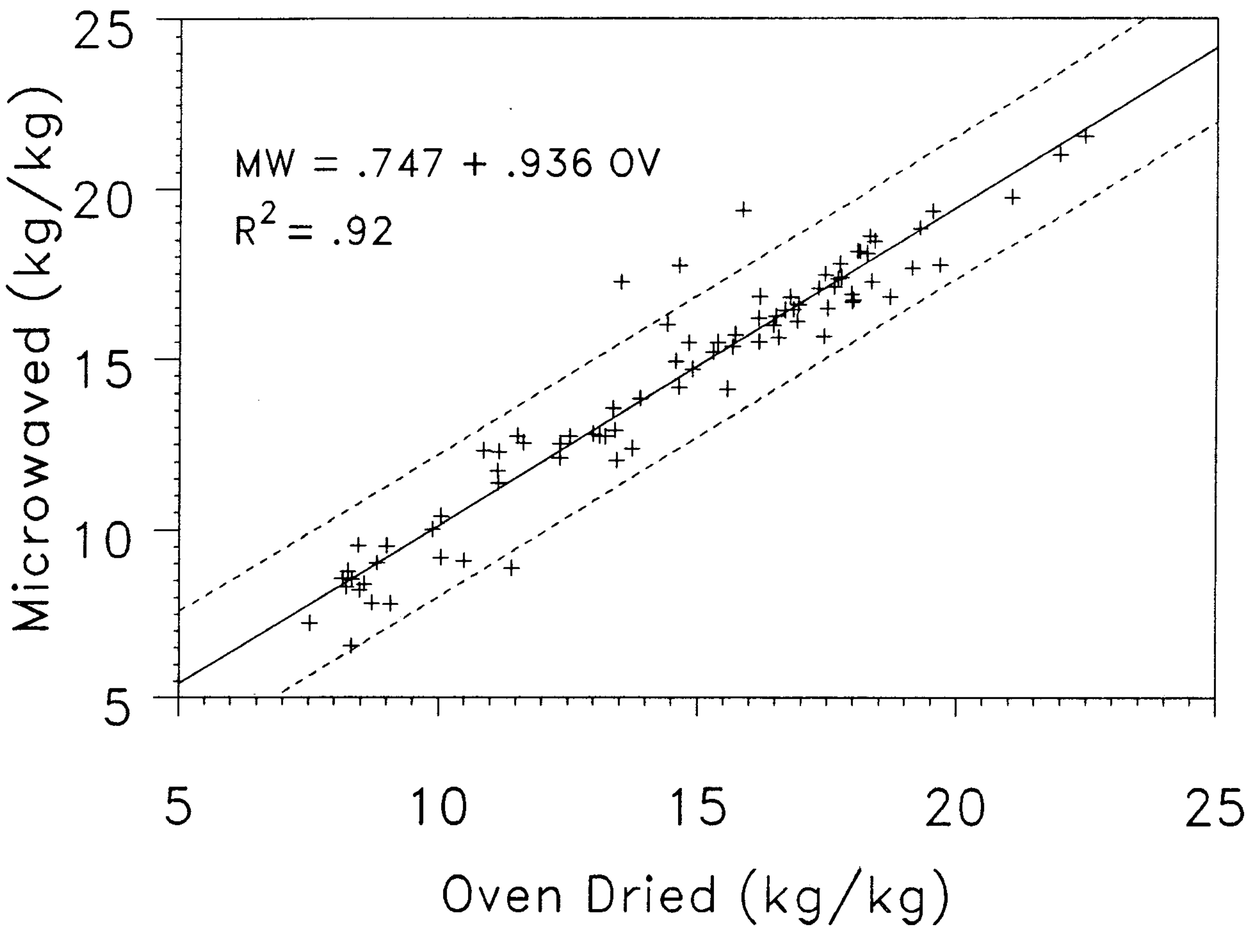

Figure 1. Plot of soil water contents measured in the microwave vs oven dried for all samples.

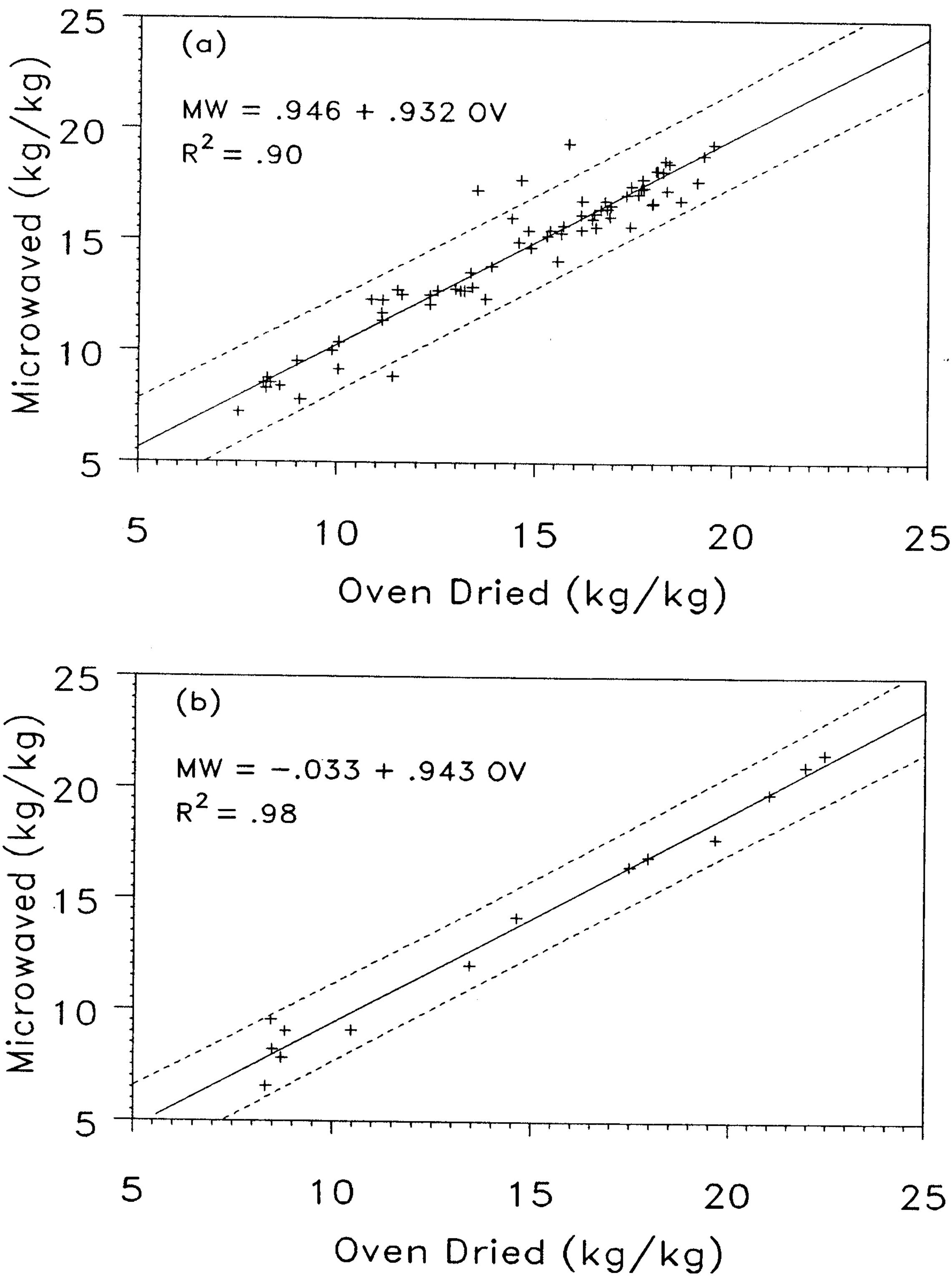

Figure 2. Plot of soil water contents measured in the microwave vs oven dried for samples (a) at the Coastal Plains Research Center and (b) at the Pee Dee Research and Education Center.

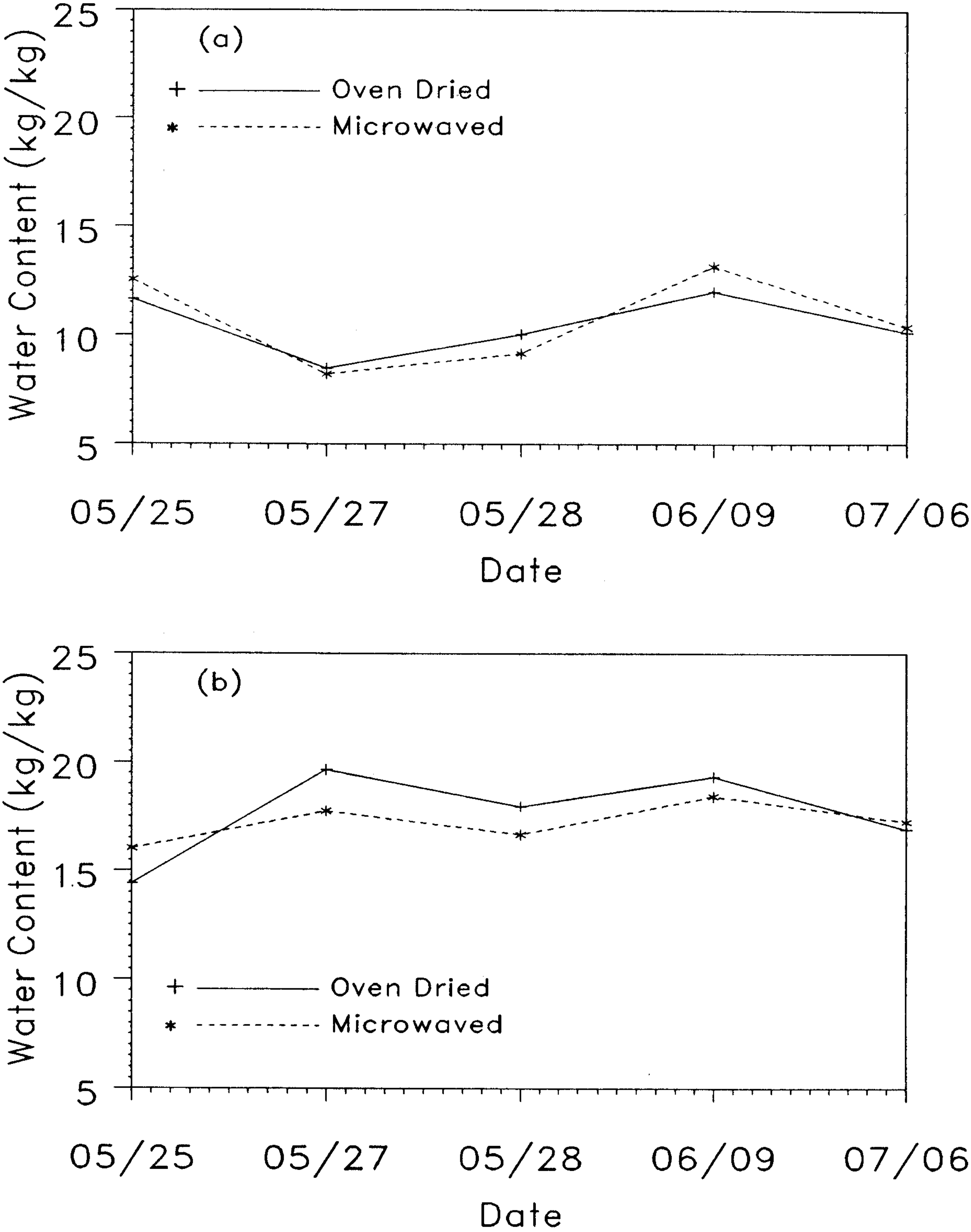

Figure 3. Plots of the microwave and oven-dried samples as a function of sampling dates for (a) the 0.30 to 0.45-m depth and (b) the 0.75 to 0.90-m depth.